The results from the Taguchi and regression analyses provide valuable insights into the dynamics of vehicle design, particularly focusing on weight, camber, and tire width's impact on the vehicle's range. The primary revelation from the Taguchi analysis is the paramount importance of weight, which significantly outstrips the other variables in influencing the vehicle's range. This finding aligns with the broader understanding in automotive engineering that weight is a critical determinant of a vehicle's efficiency and performance.

The secondary findings regarding camber and tire width, though less influential than weight, are still noteworthy. These factors, often considered secondary in traditional vehicle design, have been shown to have a measurable impact on the range. The nuanced understanding of these variables provided by the Taguchi method offers a more comprehensive view of the interplay of design elements, allowing for more informed decisions in the optimization of vehicle performance.

6.1 Weight

The Taguchi and regression analyses conducted, as detailed in the beginning of the chapter in my knowledge source, underscore the paramount importance of weight in influencing a vehicle's range. The primary revelation from these analyses is that weight significantly outstrips the other variables (camber and tire width) in its impact on the vehicle's range. This aligns with the broader understanding in automotive engineering that weight is a critical determinant of a vehicle's efficiency and performance.

Reducing the weight of a vehicle can lead to improved efficiency, as it requires less energy to accelerate and maintain motion. In electric vehicles, this is particularly crucial as it directly translates to extended range capabilities – a key performance metric. Lighter vehicles require less battery power to move, allowing for longer distances to be traveled on a single charge. Additionally, lighter vehicles also benefit from improved handling and braking performance.

6.2 Camber

Although less influential than weight, camber still plays a notable role in the vehicle's range. Camber, the angle of the wheels in relation to the ground, affects the tire footprint – the area of the tire that makes contact with the road. Proper camber settings can ensure that the tires wear evenly and maintain optimal contact with the road, which can improve vehicle stability and handling. These factors, in turn, can influence the energy efficiency of the vehicle.

However, excessive camber can lead to increased tire wear and potentially higher rolling resistance, which might negatively impact the vehicle's range. Therefore, balancing camber settings is crucial to optimizing a vehicle's performance.

6.3 Tyre Width

Tire width, ranking third in terms of influence on vehicle range, still holds significance. Wider tires generally provide better traction and stability due to a larger contact area with the road. This can be beneficial for handling, especially in electric vehicles which may have a higher center of gravity due to battery placement.

However, wider tires can also lead to increased rolling resistance, which means the vehicle's motor has to work harder to move and maintain speed, thus consuming more energy. This can adversely affect the range of an electric vehicle. Therefore, selecting the right tire width is a balance between achieving desired handling characteristics and maintaining energy efficiency.

The combined analysis of weight, camber, and tire width provides valuable insights into optimizing vehicle design for maximum efficiency and range. While weight emerges as the most critical factor, camber and tire width also contribute significantly to overall vehicle performance, especially in the context of electric vehicles where range and efficiency are paramount.

Table 6.1 : Experimentation Results

Sr. No.	Weight (N)	Camber (Degree)	Tire Width (mm)	Range (Km)
1	2400	0	100	177
2	2400	1	90	180
3	2400	2	110	176
4	2600	0	100	140
5	2600	1	110	142
6	2600	2	90	145
7	2800	0	110	133

Sr. No.	Weight (N)	Camber (Degree)	Tire Width (mm)	Range (Km)
8	2800	1	90	130
9	2800	2	100	133

6.4 Response Table for Signal-to-Noise Ratios

This section includes the analysis of signal-to-noise ratios, adhering to the 'larger is better' principle. The level of influence of each factor (weight, camber, tire width) on the vehicle's range is quantified. The delta values indicate the total variation effect each factor has on the range.

Table 6.2 : Response Table for Signal-to-Noise Ratios

Level	Weight (N)	Camber (Degree)	Tyre width (mm)
1	43.29	42.69	43.08
2	42.45	43.02	42.43
3	42.43	42.46	42.66
Delta	0.85	0.56	0.64
Rank	1	3	2

This table presents the signal-to-noise (S/N) ratios for each of the three factors (weight, camber, and tire width) at three different levels. The S/N ratio is a key metric in quality engineering and is used to measure the robustness of a system against noise factors. In the context of vehicle range, a higher S/N ratio is desirable as it indicates a greater resistance to variability and hence a more consistent performance.

1. **Data Overview**
   - Weight (N): Shows values at three levels - 43.29, 42.45, and 42.43.
   - Camber (Degree): The values are 42.69, 43.02, and 42.46 at three levels.
   - Tire Width (mm): Recorded values are 43.08, 42.43, and 42.66.
2. **Delta Values**
   - Weight: Shows the highest delta value of 0.85.
   - Tire Width: Has a delta value of 0.64.
   - Camber: Shows the lowest delta value of 0.56.

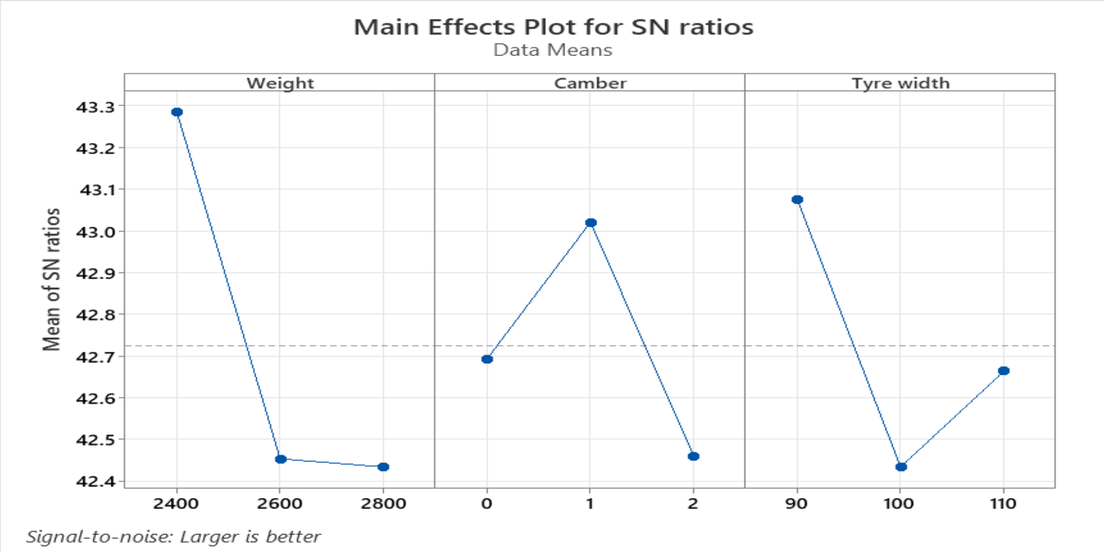

Fig. 48 : Main Effect plot for SN ratios

6.5 Analysis and Implications

1. **Dominance of Weight**: The highest delta value for weight (0.85) signifies its substantial impact on the vehicle's range. This implies that among the factors studied, weight is the most influential in affecting the range. A weight reduction could lead to a notable increase in the vehicle's range, making it a critical factor in design considerations for efficiency.
2. **Role of Tire Width and Camber**: Though less impactful than weight, tire width and camber still show notable delta values of 0.64 and 0.56, respectively. These factors, often considered secondary in traditional vehicle design, have a measurable impact on the range. The findings suggest that optimization of tire width and camber can also contribute to enhancing the vehicle's range, though their effect is relatively lesser compared to weight.
3. **'Larger is Better' Principle**: The adherence to this principle in the analysis reinforces the objective of maximizing the vehicle's range. The focus is on identifying factors that, when optimized, can lead to a larger vehicle range, which is a desirable outcome in electric and hybrid vehicle design.

The analysis of Signal-to-Noise Ratios and the resultant delta values in Table 6.1, as well as Fig. 6.1, underscore the importance of weight as a primary determinant of a vehicle’s range. Simultaneously, it highlights the significant, though lesser, roles of tire width and camber in influencing the vehicle’s range.

6.6 Response Table for Means

Here, we present the average effects of each factor at different levels. This table helps in identifying the optimal level of each factor for maximizing the vehicle's range.

Table 6.3: Response Table for Means

Level	Weight (N)	Camber	Tyre width
1	146.0	136.7	142.7
2	132.7	141.7	132.7
3	132.7	133.0	136.0
Delta	13.3	8.7	10.0
Rank	1	3	2

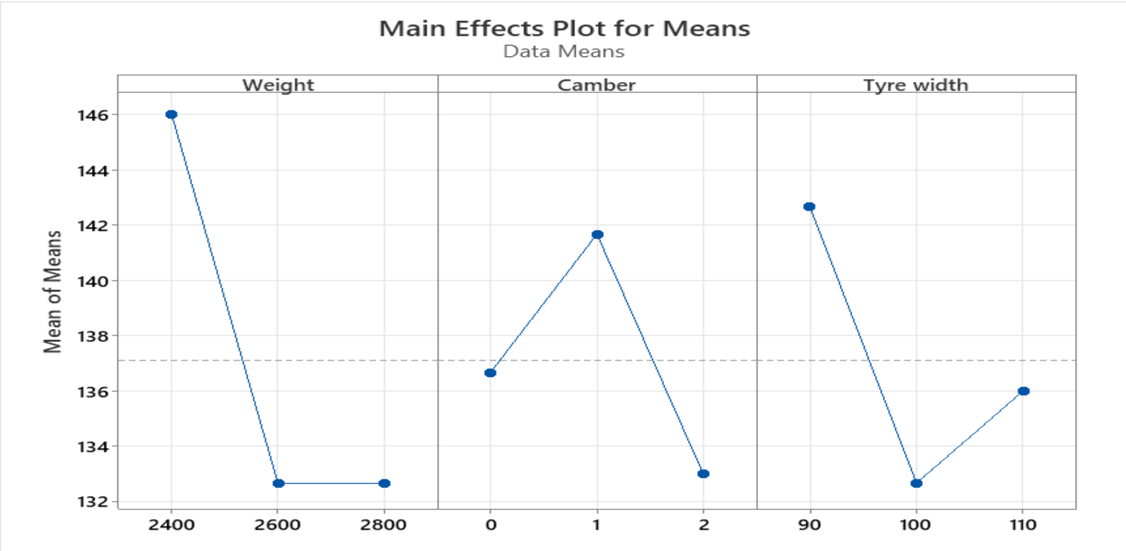

Fig. 49 : Main Effect Plot for Means

The "Response Table for Means" (Table 6.2) and its corresponding graphical representation (Fig. 6.2) in the provided document offer insights into how different levels of each factor (weight, camber, and tire width) influence the average effect on the vehicle's range. This table plays a crucial role in identifying the optimal level of each factor to maximize the vehicle's range.

1. **Impact of Weight on Range:** The weight of the vehicle continues to be the most influential factor affecting its range, as indicated by the highest delta value of 13.3. This reaffirms the earlier findings from the signal-to-noise ratio

analysis, underscoring the critical importance of weight in determining the vehicle's efficiency and range.

2. **Ranking of Factors:** The factors are ranked based on their delta values, signifying their relative impact on the vehicle's range. The rank order is consistent with the previous analysis, with weight being the most impactful, followed by tire width and camber.
3. **Optimal Levels for Maximizing Range:** By examining the average effects at different levels for each factor, one can deduce the optimal settings. For instance, a lower weight level would be more favorable for enhancing the vehicle's range.
4. **Broader Implications:** These findings have significant implications for vehicle design, particularly in the context of electric vehicles where range is a key performance metric. Designers and engineers can leverage this data to make informed decisions about material selection, vehicle dimensions, and other design aspects that directly influence weight.

The data from the "Response Table for Means" and the corresponding figure provide valuable guidance for optimizing the vehicle's design to maximize its range. The dominance of weight as a factor in vehicle range emphasizes the need for lightweight materials and efficient design in the automotive industry, particularly for electric and hybrid vehicles.

6.7 Regression Analysis: Range versus Weight, Camber, Tyre width

The regression analysis conducted in the study provides a detailed understanding of how weight, camber, and tire width affect the range of a vehicle.

6.7.1 Regression Equation

The formulation of a regression equation provides a quantitative model to predict the vehicle's range based on the three factors. This equation quantitatively models the vehicle's range based on three factors: weight, camber, and tire width.

$$Range = 258.9 - 0.0333\ X\ Weight - 1.83\ X\ Camber - 0.333\ X\ Tire\ Width$$

6.7.2 Coefficients

Table 6.4: Parametric Constant and Coefficients

Term	Coefficient	Secondary Coefficient	T-Value	P-Value	VIF
Constant	258.9	51.4	5.03	0.004	
Weight	-0.0333	0.0156	-2.13	0.086	1.00
Camber	-1.83	3.13	-0.59	0.583	1.00
Tire width	-0.333	0.313	-1.07	0.335	1.00

The coefficient for weight is -0.0333, indicating an inverse relationship between weight and the vehicle's range. This suggests that as the weight increases, the range decreases. The coefficient for camber is -1.83, also indicating an inverse relationship, though its effect is less pronounced than weight. The coefficient for tire width is -0.333, suggesting a similar inverse relationship.

6.7.3 Model Summary

- **Model Summary and ANOVA:** The summary of the regression model, including measures like R-squared and adjusted R-squared, gives insights into the model's explanatory power. The ANOVA table helps in determining the statistical significance of the model and each factor.

Table 6.5: Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
7.66014	54.65%	27.43%	0.00%

Analysis of Variance (ANOVA):

Table 6.6: ANOVA & Regression

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	353.50	117.83	2.01	0.231
Weight	1	266.67	266.67	4.54	0.086
Camber	1	20.17	20.17	0.34	0.583
Tire width	1	66.67	66.67	1.14	0.335
Error	5	293.39	58.68		
Total	8	646.89			

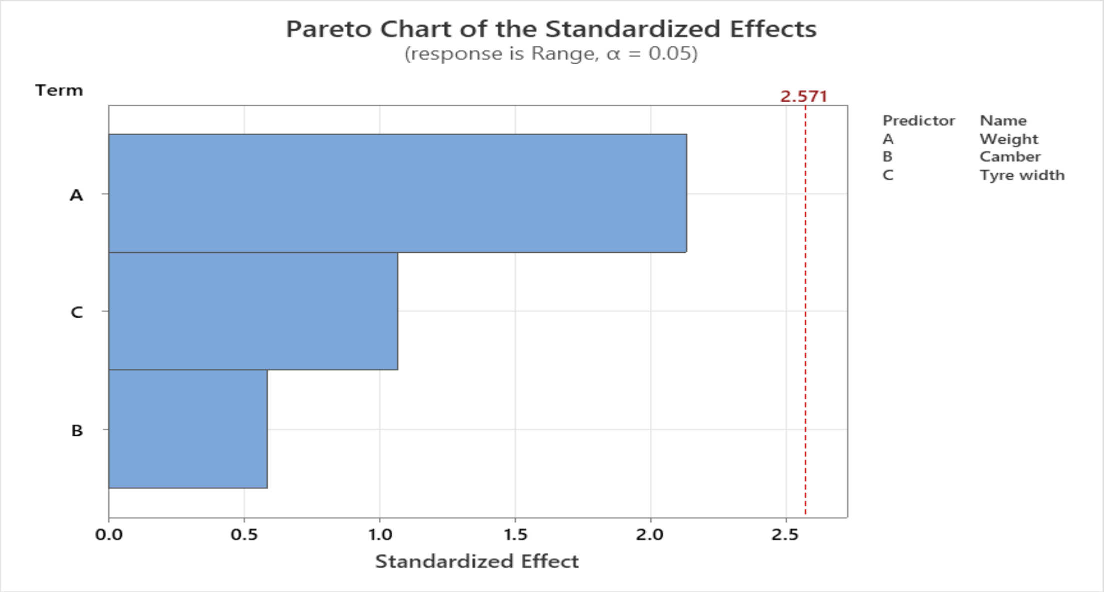

Fig. 50 : Pareto Chart of Standardized Effect

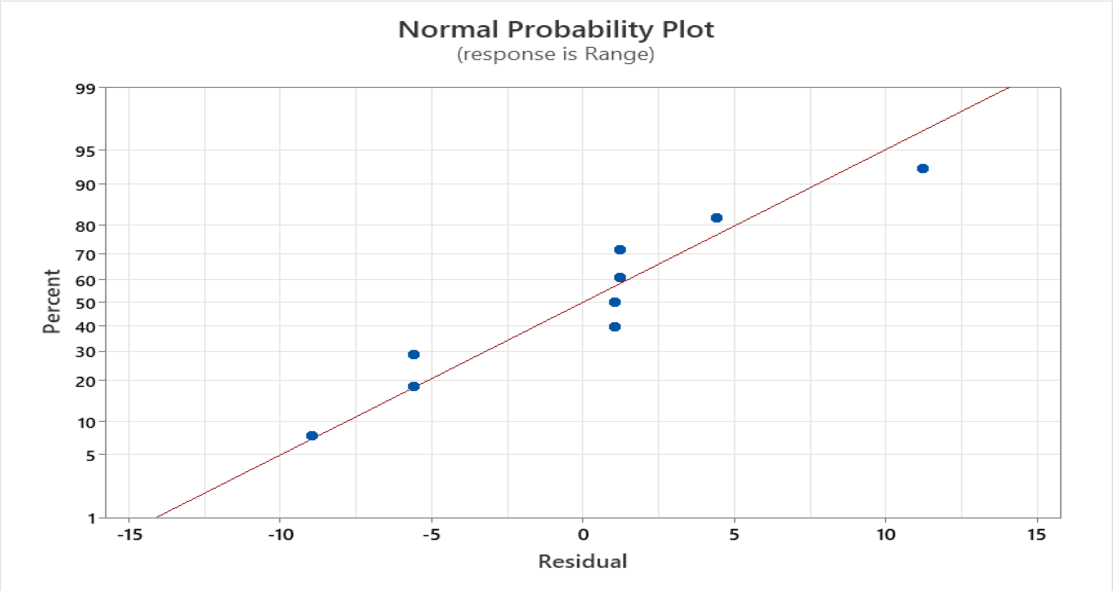

Fig. 51 : Normal Probability Plot

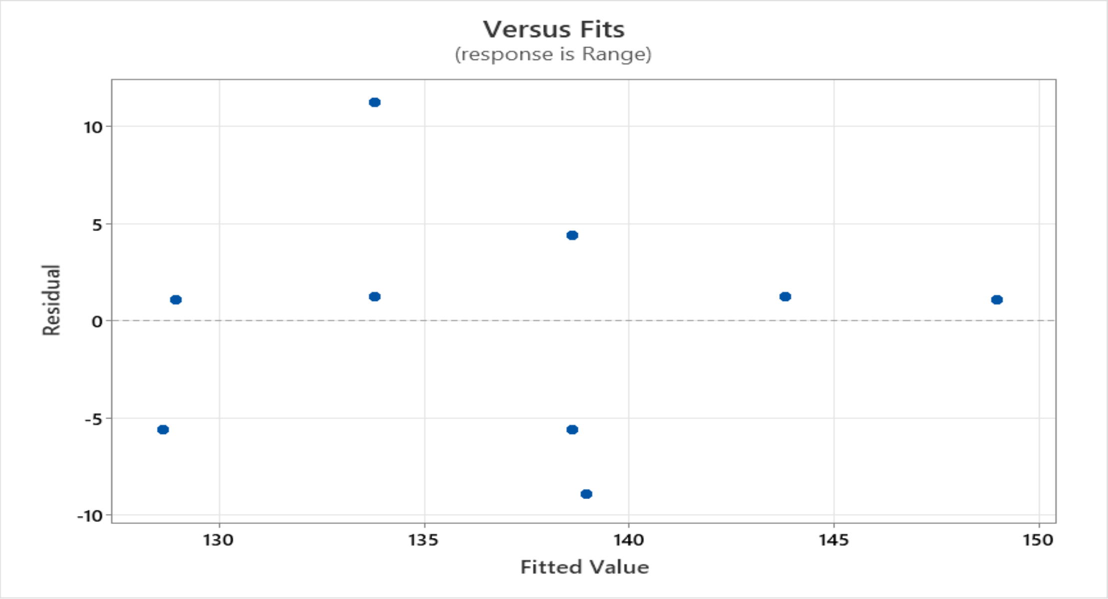

Fig. 52 : Residual Fits

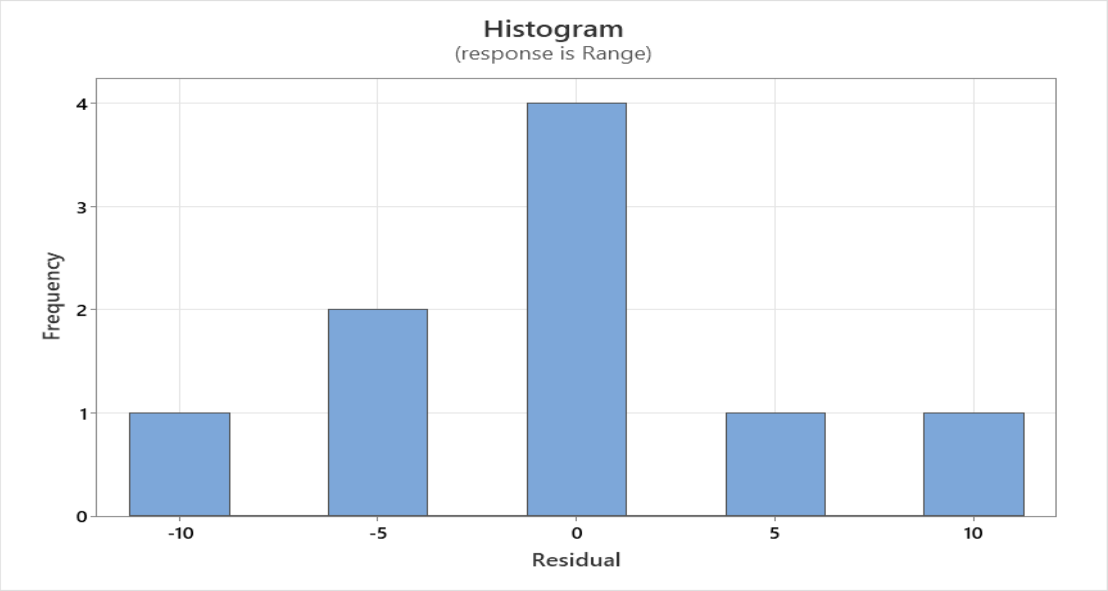

Fig. 53 : Histogram of Frequency

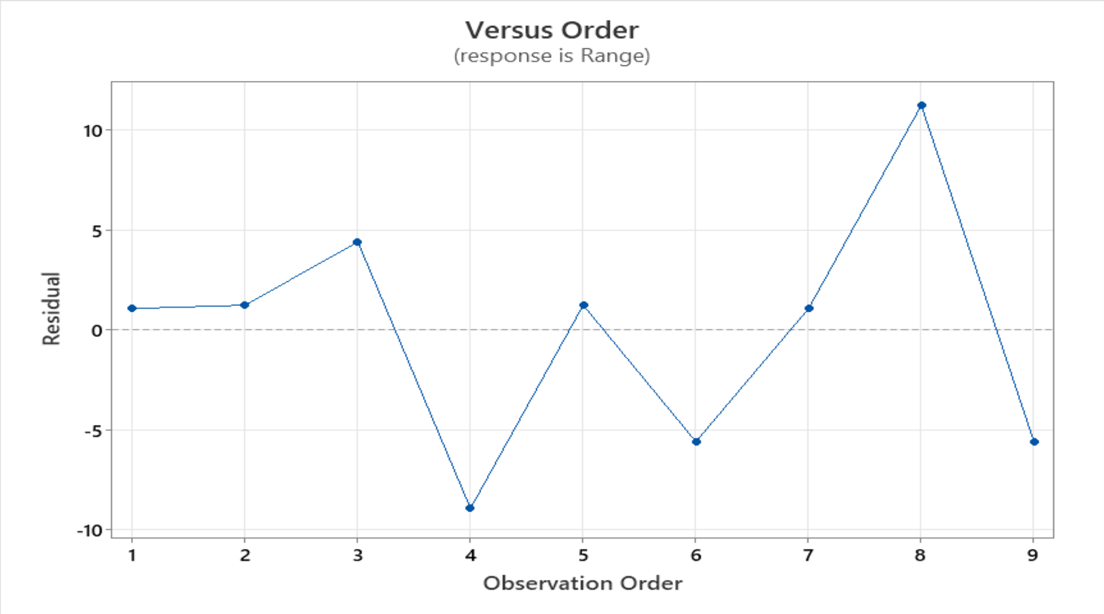

Fig. 54 : Observation Order

Model Summary and ANOVA:

The model summary includes R-squared and adjusted R-squared values which provide insights into the model's explanatory power. The R-squared value is 54.65%, and the adjusted R-squared value is 27.43%. These values indicate that while the model explains a significant portion of the variance in the vehicle's range, there might be other factors not included in the model that could affect the range.

The ANOVA (Analysis of Variance) shows the statistical significance of the model and each factor. The F-Value for weight is significant (4.54 with a P-Value of 0.086), indicating that weight is a significant predictor of vehicle range. However, the P-Values for camber and tire width are higher (0.583 and 0.335 respectively), suggesting less statistical significance.

Various figures (Fig. 6.3 to 6.7) such as the Pareto Chart of Standardized Effect, Normal Probability Plot, Residual Fits, Histogram of Frequency, and Observation Order. These graphical representations provide a visual understanding of the model's performance and the distribution of residuals.

The regression analysis confirms the inverse relationship between the range and the tested variables, especially weight. The model's moderate explanatory power indicates the potential for other factors to influence the vehicle's range, suggesting the need for further research. This analysis is crucial not only for academic purposes but also has practical implications in guiding design improvements and innovations in the automotive industry.

6.8 Main Effects and Interaction Plots for Range

This section would typically include graphical representations of the main effects and interaction effects. Main effects plots illustrate how each factor individually affects the range, while interaction plots show how the effect of one factor depends on the level of another factor.

6.8.1 Main Effects Plot for Range

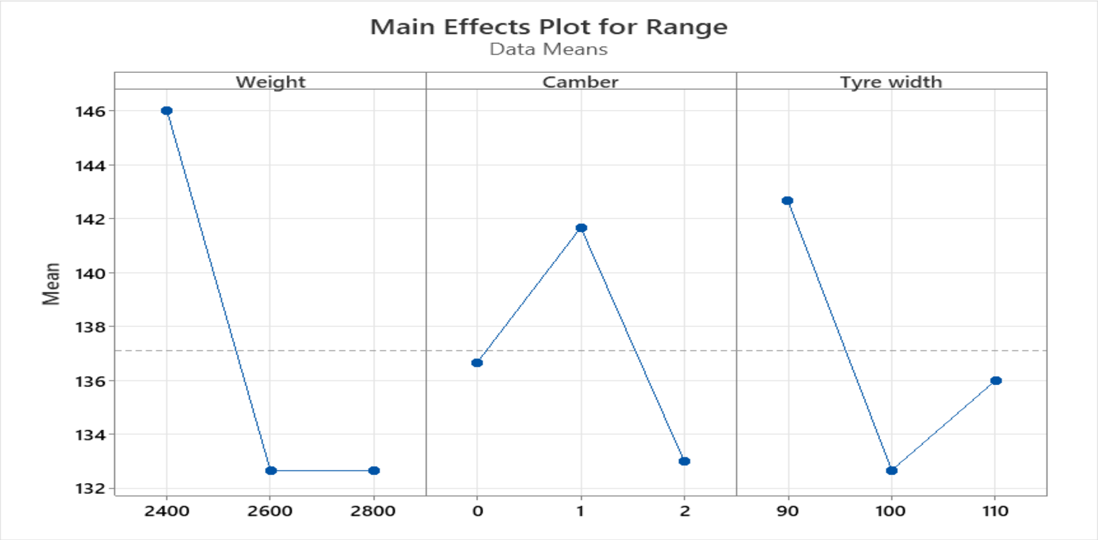

Fig. 55 : Main Effects Plot for Range

6.8.2 Interaction Plot for Range

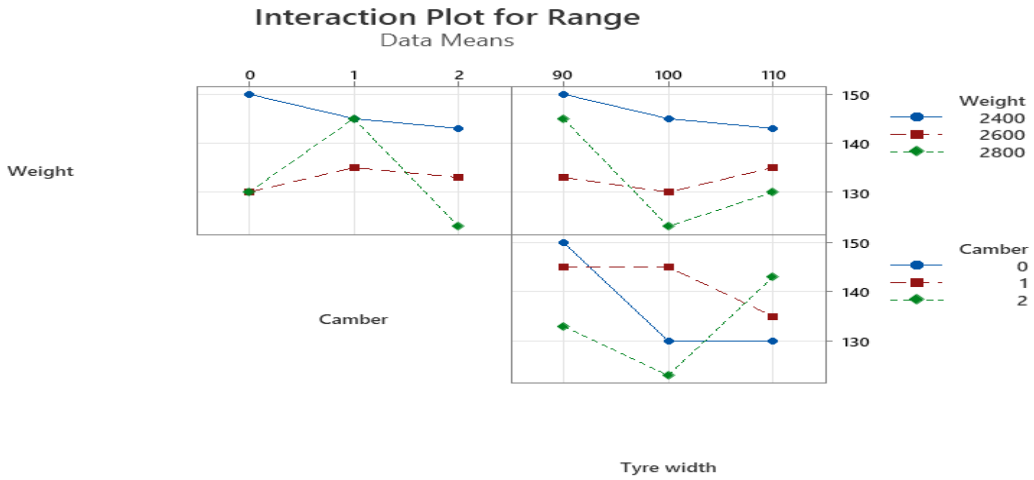

Fig. 56 : Interaction Plot for Range

This section aims to visually represent the impact of individual factors (weight, camber, and tire width) on the vehicle's range and how the effect of one factor may depend on the level of another. The observations and interpretations of these plots are crucial as they illustrate the dominance of weight in affecting the vehicle's range. These graphical representations complement the data presented in the response tables and emphasize weight's significant role in vehicle design, particularly in its influence on range. The section highlights the importance of considering these factors in the optimization of vehicle performance, providing valuable insights for automotive design and engineering.

The regression analysis, while revealing a statistically less robust model, still offers valuable insights. It confirms the inverse relationship between the range and the tested variables, especially weight. The model's moderate explanatory power (R-squared value) indicates that other unaccounted factors might be at play in determining the vehicle's range. This finding opens up new avenues for further research, suggesting that a more inclusive model incorporating additional variables could provide a more accurate and comprehensive understanding of the factors affecting vehicle range.

The discussion highlights the complexity of vehicle design and the intricate balance required between various design elements to optimize performance. The insights from these analyses are not just limited to academic interest but have practical implications in guiding design improvements and innovations in the automotive industry.

6.9 Overall Results

Table No. 6.7 : Overall Results

Parameters	Design Value	Experimental Value
Wheelbase	1800 mm	1875 mm
Track width	1200 mm	1333.5 mm
C.G. Height from Ground	417 mm	425 mm
C.G. From Front Axle	743 mm	748 mm
Ground Clearance	160 mm	158 mm
Camber	0 degree	2 degree
Castor	0 degree	1 degree
Kingpin inclination	3 degree	3.03 degree

Parameters	Design Value	Experimental Value
Scrub radius	43 mm	48 mm
Toe angle	0 degree	0 degree
Turning radius	3545.5 mm	4604.2 mm
Maximum Speed	60 kmph	58 kmph
Maximum Range	180 km	185 km

The design value was 1800 mm, while the experimental value turned out to be slightly longer at 1875 mm. The track was designed at 1200 mm, and the experimental measurement was 1333.5 mm, indicating a wider stance than planned. The Center of Gravity (C.G.) height from the ground initially set at 417 mm, the experimental value was slightly higher at 425 mm. C.G. distance from the front axle was closely matched, with the design at 743 mm and the experimental result at 748 mm. The vehicle was designed with a clearance of 160 mm but was marginally lower at 158 mm in the experimental setup. While the design camber was specified 0 degrees, the experimental camber value optimized by experimentation was adjusted to 2 degrees. Like the camber, castor also saw a change from the designed 0 degree to 1 degree in the experimental results. Kingpin Inclination (KPI) was almost accurately achieved with a design value of 3 degrees and an experimental value of 3.03 degrees. The design value of scrub radius was 43 mm, but the experimental value increased to 48 mm. Both the design and experimental values were maintained at 0 degrees. There was a significant increase from the designed 3545.5 mm of turning radius to an experimental value of 4604.2 mm. The designed speed was 60 kmph, which slightly decreased to 58 kmph in the experimental tests. Both the designed and experimental values were consistent at 180 km.